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(54) Deflection enhancement for continuous ink jet printers

(57) A continuous ink jet printer having improved ink drop placement and image quality insuring from importing enhanced lateral flow characteristics, by geometric obstruction (20) within it's ink delivery channel (4), which, in turn, enables enhanced ink drop deflection.

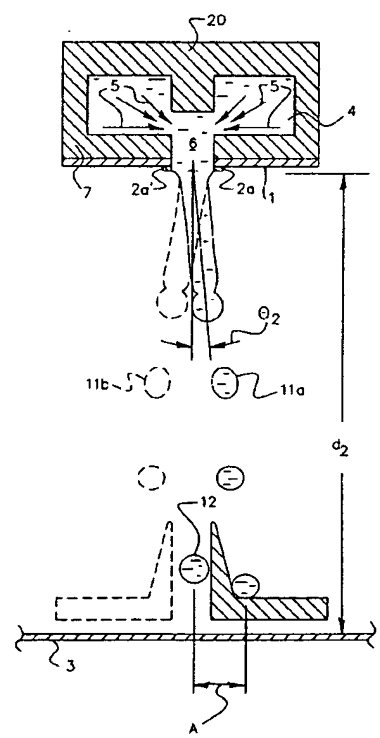

FIG. 4

EP 1 110 732 A2

Description

[0001] The present invention relates generally to the field of digitally controlled ink jet printing systems. It particularly relates to improving those systems that asymmetrically heat a continuous ink stream, in order to deflect the stream's flow between a non-print mode and a print mode.

[0002] Ink jet printing is only one of many digitally controlled printing systems. Other digital printing systems include laser electrophotographic printers, LED electrophotographic printers, dot matrix impact printers, thermal paper printers, film recorders, thermal wax printers, and dye diffusion thermal transfer printers. Ink jet printers have become distinguished from the other digital printing systems because of the ink jet's non-impact nature, its low noise, its use of plain paper, and its avoidance of toner transfers and filing.

[0003] The ink jet printers can be categorized as either drop-on-demand or continuous systems. However, it is the continuous ink jet system which has gained increasingly more recognition over the years. Major developments in continuous ink jet printing are as follows:

[0004] Continuous ink jet printing itself dates back to at least 1929. See U.S. Patent 1,941,001 which issued to Hansell that year.

[0005] U.S. Patent No. 3,373,437, which issued to Sweet et al. in March 1968, discloses an array of continuous ink jet nozzles wherein ink drops to be printed are selectively charged and deflected towards the recording medium. This technique is known as binary deflection continuous ink jet printing, and is used by several manufacturers, including Elmjet and Scitex.

[0006] U.S. Patent No. 3,416,153, issued to Hertz et al. in December 1968. It discloses a method of achieving variable optical density of printed spots, in continuous ink jet printing. Therein the electrostatic dispersion of a charged drop stream serves to modulate the number of droplets which pass through a small aperture. This technique is used in ink jet printers manufactured by Iris.

[0007] U.S. Patent No. 4,346,387, also issued to Hertz, but it issued in 1982. It discloses a method and apparatus for controlling the electrostatic charge on droplets. The droplets are formed by the breaking up of a pressurized liquid stream, at a drop formation point located within an *electrostatic charging tunnel,* having an electrical field. Drop formation is effected at a point in the electric field, corresponding to whatever predetermined charge is desired. In addition to charging tunnels, deflection plates are used to actually deflect the drops.

[0008] Until recently, conventional continuous ink jet techniques all utilized, in one form or another, *electrostatic charging tunnels* that were placed close to the point where the drops are formed in a stream. In the tunnels, individual drops may be charged selectively. The selected drops are charged and deflected downstream by the presence of deflector plates that have a large potential difference between them. A gutter (sometimes referred to as a "catcher") is normally used to intercept the charged drops and establish a non-print mode, while the uncharged drops are free to strike the recording medium in a print mode as the ink stream is thereby deflected, between the "non-print" mode and the "print" mode.

[0009] A continuous ink jet printer system has been suggested which renders the above-described *electrostatic charging tunnels* unnecessary. Additionally, it serves to better couple the functions of (1) droplet formation and (2) droplet deflection. The printer system comprises an ink delivery channel, a source of pressurized ink in communication with the ink delivery channel, and a nozzle having a bore which opens into the ink delivery channel, from which a continuous stream of ink flows. A droplet generator inside the nozzle causes the ink stream to break up into a plurality of droplets at a position spaced from the nozzle. The droplets are deflected by heat from a heater (in the nozzle bore) which heater has a selectively actuated section, i.e. a section associated with only a portion of the nozzle bore. Selective actuation of a particular heater section, at a particular portion of the nozzle bore produces what has been termed an asymmetrical application of heat to the stream. Alternating the sections can, in turn, alternate the direction in which this asymmetrical heat is applied and serves to thereby deflect the ink droplets, inter alia, between a "print" direction (onto a recording medium) and a "non-print" direction (back into a "catcher").

[0010] Asymmetrically applied heat results in stream deflection, the magnitude of which depends upon several factors, e.g. the geometric and thermal properties of the nozzles, the quantity of applied heat, the pressure applied to, and the physical, chemical and thermal properties of the ink. Although solvent-based (particularly alcohol-based) inks have quite good deflection patterns, and achieve high image quality in asymmetrically heated continuous ink jet printers, water-based inks until now, have not. Water-based inks require a greater degree of deflection for comparable image quality than the asymmetric treatment, jet velocity, spacing, and alignment tolerances have in the past allowed. Accordingly, a means for enhancing the degree of deflection for such continuous ink jet systems, within system tolerances would represent a surprising but significant advancement in the art and satisfy an important need in the industry for water-based, and thus more environmentally friendly inks.

[0011] It is therefore a principal object of the present invention to improve the magnitude of ink droplet deflection within continuous ink jet asymmetrically heated printing systems, without negating otherwise acceptable system tolerances.

[0012] With the above object in view, the invention is defined by the several claims appended hereto.

[0013] According to an aspect of the invention, lateral flow of ink entering the nozzle bore section of a continuous ink jet printer system is increased. The printer system is of the type employing asymmetrical heating for

drop deflection. Said lateral flow is increased by imposing particular geometric obstructions at a position upstream from the nozzle bore entrance.

[0014] Figure 1 shows a schematic diagram of an exemplary continuous ink jet print head and nozzle array as a print medium (e.g. paper) rolls under the ink jet print head.

[0015] Figure 2 is a cross-sectional view of one nozzle tip from a prior art nozzle array showing d_1 (distance to print medium) and θ_1 (angle of deflection).

[0016] Figure 3 shows a top view directly into a nozzle with an asymmetric heater surrounding the nozzle.

[0017] Figure 4 is a cross-sectional view of one nozzle tip from one embodiment of the present invention showing d_2 and θ_2.

[0018] Figure 5 is a cross-sectional view of one nozzle tip from a preferred embodiment of the present invention showing d_3 and θ_3.

[0019] Figure 6 is a graph illustrating the relationships between d_1 - d_3, θ_1 - θ_3, and A.

[0020] The present description will be directed, in particular, to elements forming part of, or cooperating directly with, apparatus or processes of the present invention. It is to be understood that elements not specifically shown or described may take various forms well known to those skilled in the art.

[0021] Referring to Figure 1, a continuous ink jet printer system is generally shown at 10. The print head 1, from which extends an array of nozzle heaters 2, houses heater control circuits (not shown) which process signals to an ink pressure regulator (not shown).

[0022] Heater control circuits read data from the image memory, and send time-sequenced electrical pulses to the array of nozzle heaters 2. These pulses are applied at an appropriate time, and to the appropriate nozzle, so that drops formed from a continuous ink jet stream will form spots on a recording medium 3, in the appropriate position designated by the data sent from the image memory. Pressurized ink travels from an ink reservoir (not shown) to an ink delivery channel 4 and through nozzle array 2 onto either the recording medium 3 or the gutter 9.

[0023] Referring now to Figure 2, an enlarged cross-sectional view of a single nozzle heater 2a/2a' from among the nozzle array 2 shown in Figure 1, is illustrated, as it is in the prior art. Note that ink delivery channel 4 shows arrows 5 that depict a substantially vertical flow pattern of ink headed into nozzle bore 6. There is a relatively thick wall 7 which serves, inter alia, to insulate the ink in the channel 4 from heat generated in the nozzle heater 2a/2a'. Thick wall 7 may also be referred to as the "orifice membrane." An ink stream 8 forms as a meniscus of ink initially leaving the nozzle 2a/2a'. At a distance below the nozzle 2a/2a' ink stream 8 breaks into a plurality of drops 11.

[0024] Figure 3 is an expanded bottom view of heater 2a/2a' showing the line 2-2, along which line the Figure 2 cross-sectional illustration is viewed. Heater 2a/2a' can be seen to have two sections (sections 2a and 2a'). Each section covers approximately one half of the nozzle bore opening 6. Alternatively, heater sections can vary in number and sectional design. One section provides a common connection G, and isolated connection P. The other has G' and P' respectively. Asymmetrical application of heat merely means applying electrical current to one or the other section of the heater independently. By so doing, the heat will deflect the ink stream 8, and deflect the drops 11, away from the particular source of the heat. For a given amount of heat, the ink drops 11 are deflected at an angle θ_1 (in Figure 2) and will travel a vertical distance d_1 onto recording media 3 from the print head. There also is a distance "A", which distance defines the space between where the deflection angle θ_1 would place the deflected drops 11 on the recording media (or a catcher) and where the drops 12 would have landed without deflection. The stream deflects in a direction anyway from the application of heat. The ink gutter 9 is configured to catch deflected ink droplets 11 while allowing undeflected drop 12 to reach a recording medium. An alternative embodiment of the present invention could reorient ink gutter ("catcher") 9 to be placed so as to catch undeflected drops 12 while allowing deflected drops 11 to reach the recording medium.

[0025] The ink in the delivery channel emanates from a pressurized reservoir (not shown), leaving the ink in the channel under pressure. In the past the ink pressure suitable for optimal operation would depend upon a number of factors, particularly geometry and thermal properties of the nozzles and thermal properties of the ink. A constant pressure can be achieved by employing an ink pressure regulator (not shown).

[0026] Referring to Figure 4, in the operation of the present invention, the *lateral* course of ink flow patterns 5 in the ink delivery channel 4, are enhanced by, a geometric obstruction 20, placed in the delivery channel 4, just below the nozzle bore 6. This lateral flow enhancing obstruction 20 can be varied in size, shape and position, but serves to improve the deflection by many times x, based upon the lateralness of the flow and can therefore reduce the dependence upon ink properties (i.e. surface tension, density, viscosity, thermal conductivity, specific heat, etc.), nozzle geometry, and nozzle thermal properties while providing greater degree of control and improved image quality. Preferably the obstruction 20 has a lateral wall parallel to the reservoir side of wall 7, such as squares, cubes, rectangles, triangles, etc. The deflection enhancement may be seen by comparing for example the margins of difference between θ_1 of Figure 2 and θ_2 of Figure 4. This increased stream deflection enables improvements in drop placement (and thus image quality) by allowing the recording medium 3 to be placed closer to the print head 1 (d_2 is less than d_1) while preserving the other system level tolerances (i.e. spacing, alignment etc.) for example see distance A. The orifice membrane or wall 7 can also be thinner. We have found

that a thinner wall provides additional enhancement in deflection which, in turn, serves to lessen the amount of heat needed per degree of the angle of deflection θ_2.

[0027] Referring now to Figure 5 drop placement and thus image quality can be even further enhanced by an obstruction 20 which provides almost total lateral flow at the entrance to nozzle bore 6. The distance d_3 to print medium 3 is again lessened per degree of heat because deflection angle θ_3 can be increased per unit temperature.

[0028] Figure 6 shows the relationship of a constant drop placement A as distances to the print media d_1, d_2, and d_3 become less and less and as deflection angles θ_1, θ_2, and θ_3 become increasingly larger. As a consequence of enhanced lateral flow, the ability to miniaturize the printer's structural dimensions while enhancing image size and enhancing image detail is achieved.

Claims

1. Apparatus for controlling ink in a continuous ink jet printer in which a continuous stream of ink (8) is emitted from a nozzle, said apparatus comprising:

   an ink delivery channel (4) having disposed therein a geometric obstruction (20) to include lateral flow of the ink at a predetermined magnitude;
   a source of pressurized ink;
   the source of pressurized ink communicating with the ink delivery channel;
   a nozzle bore (6) which opens into the ink delivery to establish a continuous flow of ink in a stream, the nozzle bore defining a nozzle bore perimeter; and
   a nozzle heater having a selectively actuated section (2a, 2a') associated with only a portion of the nozzle bore perimeter, whereby actuation of the heater section produces an asymmetric application of heat to the stream which controls the stream direction thereby enabling the stream to deflect in a direction away from the applied heat, and which deflection is in a magnitude proportional to the lateral flow magnitude.

2. The apparatus of claim 1, wherein the geometric obstruction has a lateral wall parallel to the orifice membrane wall.

3. The apparatus of claim 2, wherein the geometric obstruction's lateral wall has a length which is proportional to the magnitude of the lateral flow.

4. The apparatus of claim 2, wherein the geometric obstruction is selected from the group of geometrics consisting of rectangular, square, cubical and triangular.

5. Apparatus of claim 1, wherein the magnitude of deflection is enhanced as the orifice membrane wall is reduced in thickness.

6. A method for improving the image quality of the continuous ink jet printer of claim 1, said method comprising increasing the lateral ink flow in order to increase the magnitude of deflection.

7. The method of claim 6, further comprising reducing the orifice membrane wall's thickness in order to improve deflection.

8. The apparatus of claim 1, further comprising a distance (d_1, d_2, d_3) between the nozzle heater and a recording medium (3) onto which the ink prints, said distance being less than such distance for ink jet printers having no geometric obstructions to induce lateral flow.

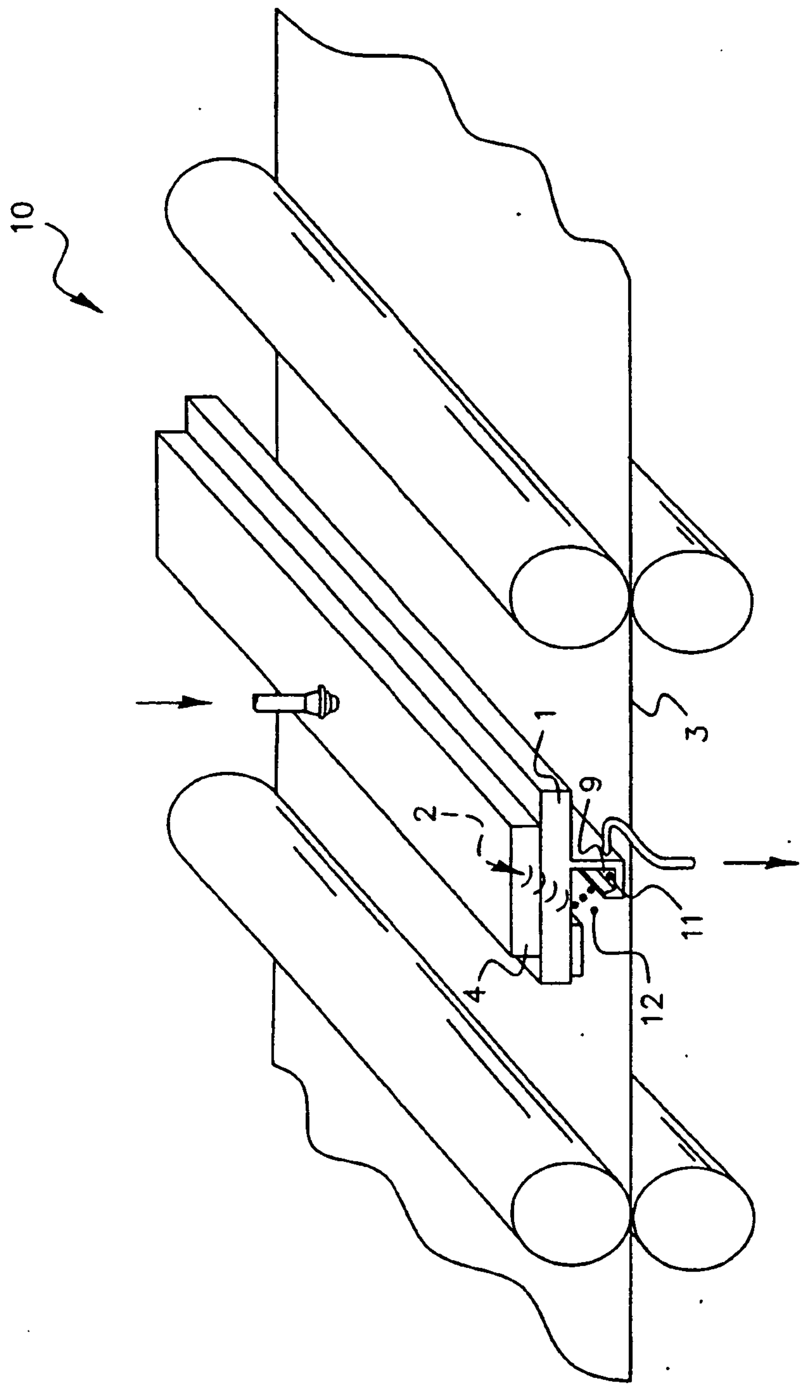

FIG. 1

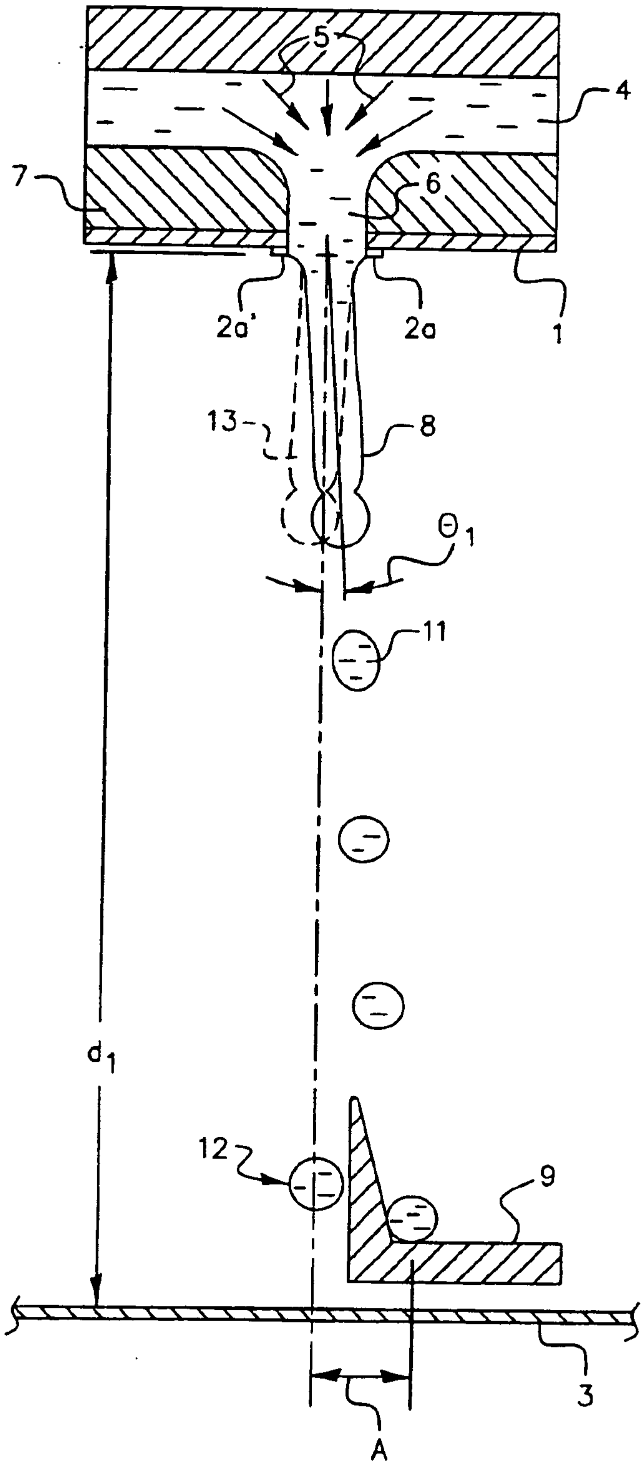

FIG. 2 (prior art)

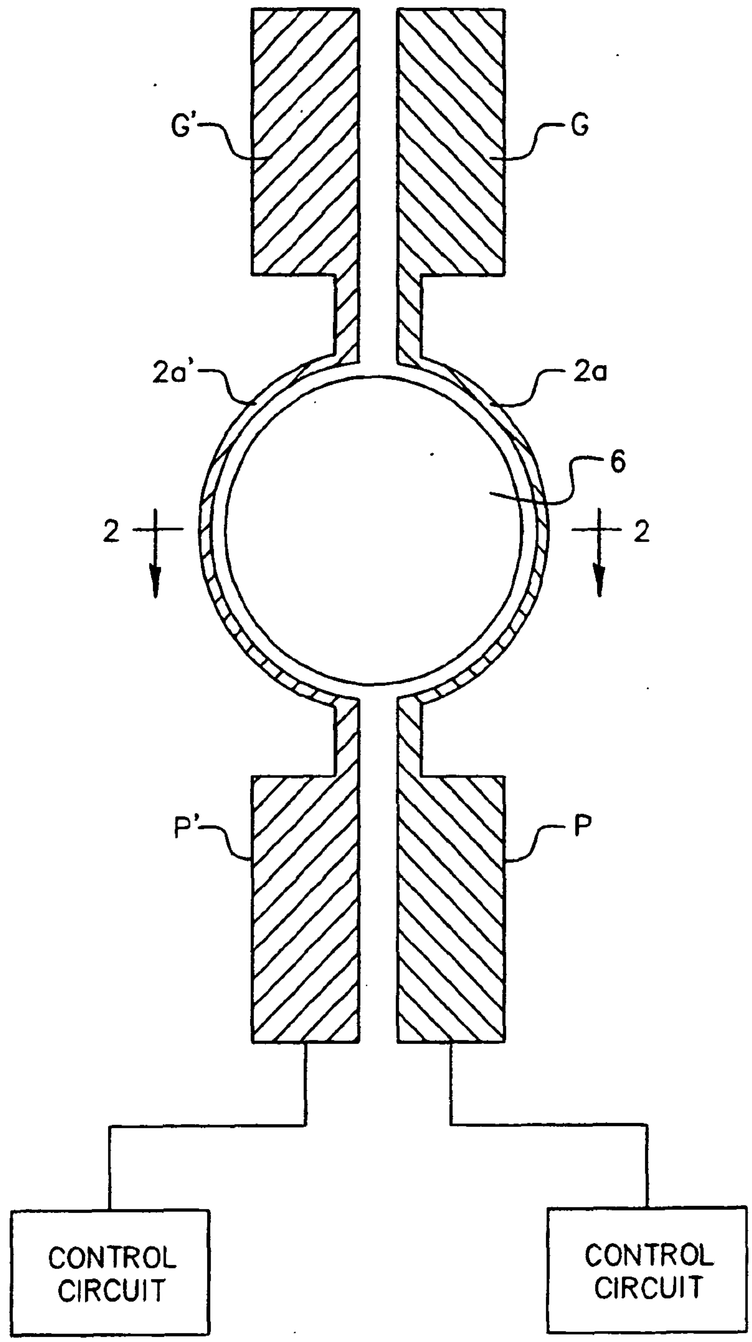

FIG. 3

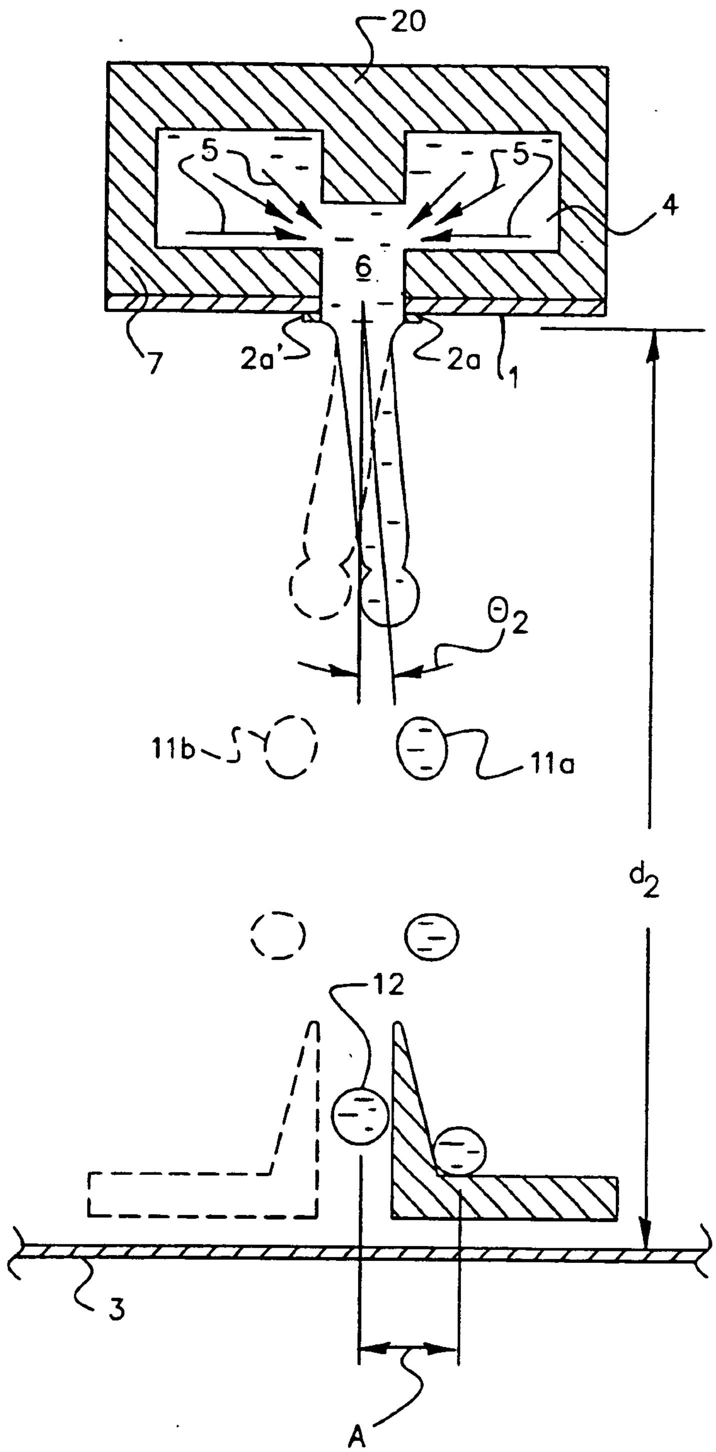

FIG. 4

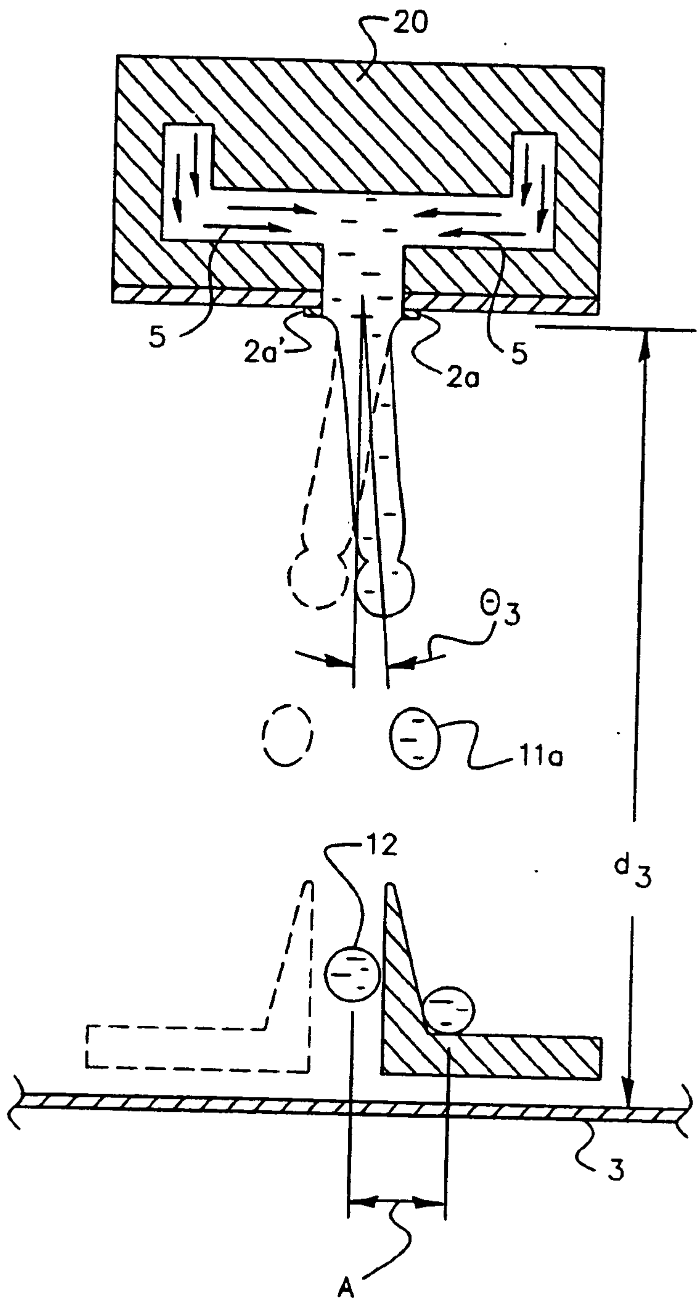

FIG. 5

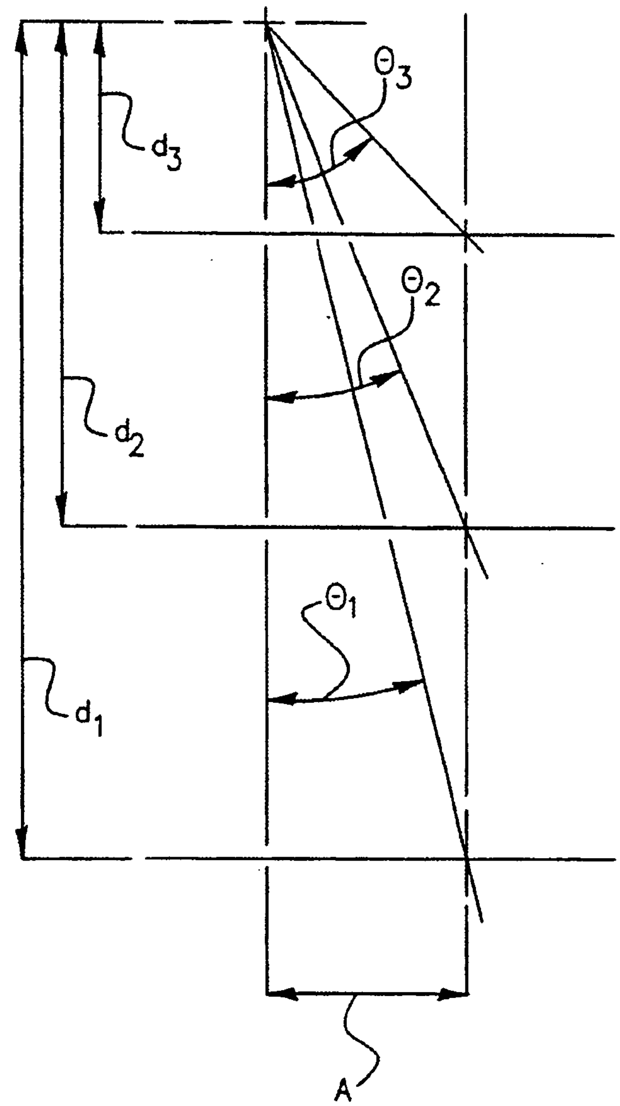

FIG. 6